ULTRASONIC WELDING PROCESS AND EQUIPMENT FOR CONSTRUCTION OF ELECTRON-TUBE MOUNTS

Thirteenth Quarterly Progress Report
For the Period
July 1 through September 30, 1965

Contract No. DA-36-039-sc86741
Order No. 19063-PP-62-81-81

Placed by
Industrial Engineering Division
United States Army Electronics Command
225 South Eighteenth Street
Philadelphia, Pennsylvania

AEROPROJECTS INCORPORATED
West Chester, Pennsylvania

ULTRASONIC WELDING PROCESS AND EQUIPMENT FOR CONSTRUCTION OF ELECTRON-TUBE MOUNTS

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The object of this program is to design and construct prototype welding equipments and their associated accessories to perform by ultrasonic techniques the welding operations required in the assembly of electron tubes.

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Specifications SCS-114A, SCIPPR-15
and MIL-E-1/1121A

Report Prepared by: J. Thomas

Report Approved by: J. B. Jones

FOREWORD

The Twelfth Quarterly Progress Report was replaced by a brief letter report submitted to the United States Army Electronics Command. The letter was not distributed.

ABSTRACT

Fabrication of the sample lot of 100 type 6080WB electron tubes was completed up to the last step in the assembly sequence. The last step could not be carried out because of a part change made by Tung-Sol since this effort was initiated. A method of adapting equipment and procedures to the current production part is being sought.

Electrical tests showed that most of the tubes in the sample lot had short circuits. The cause was found to be incorrect assembly prior to welding, not faulty welded joints. Appropriately modified inspection procedures will be used in fabricating a second sample lot.

Components welding was completed. Welding of 0.003-inch tungsten-rhenium (W-3Re) wire was carried out with a 300-watt welder. Bond strengths of wires welded to nickel and molybdenum sheets were significantly less than the satisfactory strengths obtained previously with a 600-watt welder. Wires could be welded to tungsten sheet with the 300-watt welder, and average tensile-shear strength of the bonds was 26 percent of the wire strength.

Frame grid welding was carried out with a 4-kw welder in an attempt to weld all wire turns on one side rod simultaneously. Satisfactory bonding of all wires was not achieved with this approach, and further effort in this direction was discontinued.

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PURPOSES

The objectives of this Production Engineering Measure (PEM) are to:

1. Demonstrate the capability limits of ultrasonic welding to join combinations of metallic materials of interest to the electron-tube industry. Devote major effort to making satisfactory joints in materials and geometries which might be difficult or impossible to join by other means.

2. Analyze the welding requirements for a specific electron tube - Type 6080WB. This type was selected by the U. S. Army Electronics Command because it has a record of rejects and failures due to metallic splatter caused by conventional welding techniques and improperly welded joints.

3. Redesign components of the Type 6080WB electron-tube where possible, to permit ultrasonic welding of joints previously found impractical. This effort will result in a tube mount with as many metal-to-metal joints as possible produced by ultrasonic welding so that evaluation of electron-tube performance will not be confused by the influence of metal-to-metal joints produced by other welding or joining techniques.

4. Determine the feasibility of joining 0.003-inch gold-plated molybdenum grid wires to 0.060-inch molybdenum side bars by ultrasonic welding for frame grid manufacture. If successful, redesign applicable components of the Type 6080WB electron-tube mount to permit the use of frame grids.

5. Prepare fixturing and tooling for the Type 6080WB electron tube, compatible with ultrasonic welding equipment.

6. Ultrasonically weld the parts required to assemble electron-tube mounts for the 6080WB tube type, and compare results obtained against similar sub-assemblies made by conventional joining methods. Tests will include strength and environmental tests.

7. Build production ultrasonic welding equipment which will enable an electron-tube manufacturer to make the welded connections in a broad range of electron-tube types.

8. Install the ultrasonic welding equipment in a production company, and produce on a pilot basis with that company's personnel a limited lot size of Type 6080WB electron tubes for subsequent evaluation in accordance with the applicable military specification.

NARRATIVE AND DATA

I. ELECTRON TUBE STUDY

Preparation of materials and components for the sample lot of 6080WB electron tubes was not completed until early in August, partly because the Tung-Sol plant was closed for vacation from July 19 through July 30. In August fabrication of the sample lot was initiated at Tung-Sol, with Mr. T. A. Walraven of Aeroprojects assisting.

During the early assembly sequences, it was discovered that the anode connectors prepared for tube fabrication were wider at the end to be welded than those used in earlier assemblies. The connectors extended beyond the welding tip then adopted, so that cut-through occurred during welding. However, modified grid connectors were used, which were substantially the same as the earlier anode connectors and from which satisfactory results were obtained.

Welding of the anode eyelets was made difficult by variations in hardness of the anode rods. The importance of uniform annealing of the anode rods has been discussed in previous reports. In the present case, the anodes were "pinned" (anode rods were inserted into carbon anodes) and fired in one lot. Since all parts were not of uniform hardness after annealing, it was suspected that either a non-uniform heat distribution existed in the hydrogen furnace or the parts were not uniformly exposed to the heat cycle. The grooved insert of the A-2 anvil cracked repeatedly during the anode eyelet welding operation, presumably because of the hardness of some of the anode rods.

No further major difficulties were encountered until the last step of the assembly sequence, welding snubbers to snubber supports (Sequence No. 11, Eleventh Quarterly Progress Report), when the ceramic spacers cracked. It was discovered that the Fotoceram spacers used in earlier work and during tool design and welding development had been replaced with AlSiMag spacers. The alumina (AlSiMag) spacers are now used in current production of the 6080WB tube. They reportedly provide improved performance in terms of temperature stability and eliminate the cracking tendency prevalent in the Fotoceram spacers during standard bulbing operations. Since a reversion to Fotoceram spacers was not possible because of unavailability of material, and since USAECOM representatives urged the use of standard production parts, assembly with the alumina spacers was continued. Efforts to alleviate cracking the spacer during welding were directed toward tooling modifications, including restraint of the cage assembly; however, no successful solution to the problem was found during this period.

In order to obtain preliminary electrical performance data on the tube assemblies, six units were selected from the sample lot and tested

according to MIL-E-1/1121 A, 9 September 1960 (Acceptance Inspection, Part 1). All six completed tubes were defective because of heater-cathode short circuits. Electrical tests of the remaining lot of tubes (prior to bulbing and basing) indicated that the majority of the tubes also displayed heater-cathode and/or grid-plate short circuits. Since no electrical test checks had been carried out during fabrication, the tubes were inspected thoroughly to determine the reasons for the shorts. It was discovered that the ferrules surrounding the heater wire leads were misplaced, permitting insufficient projection of the ceramic insulator containing the heater wires beyond the cathode sleeve. As a result, the heater wires were in contact with the cathode sleeve, causing short circuiting. In addition, slight bowing of the laterals of the frame grid was observed, particularly near the ends of the grid frame.

A solution to the problem of the bowed laterals was pursued by making a series of test assemblies and observing at what stage of the cage assembly the grid deformation occurred. Particular attention was paid to the welding of the grid eyelets to determine whether the welding operation distorted the grid assembly. Observation of the laterals was made possible by cutting away a portion of the carbon anode and inspecting the assembly with an optical shadowgraph during the fabrication sequences. The results of these investigations indicated that the welding operations did not cause grid distortion. Several assemblies contained bowed laterals after manual assembly of the cage components, prior to welding, caused presumably by distortion of the grid during manual assembly. The apparent reason for the majority of the grid-anode shorts, however, was traced to twisting of the grid connector into position for the stem leads after cage assembly was completed. The twist was necessary because the grid connector was welded to the leg of the grid frame in an improper angular orientation to the stem lead, to which it was to be subsequently welded. The misalignment of the connector was corrected by twisting into proper position, thereby distorting the grid frame and bowing the laterals, providing contact with the anode. The stem leads used in these assemblies were bent manually into approximate orientation, since the mechanical bending and trimming die used in production assembly could not be used because of the crimp in the leads. This problem can be alleviated in future assemblies by care in assembly and proper positioning of the grid connector and stem leads prior to welding.

The heater-cathode shorts were caused by improper assembly of the heater sub-assembly and positioning within the cathode sleeve. The ferrules (sleeves) surrounding the heater lead wires are usually pressed onto the leads after the heater is inserted into its ceramic insulator. Tung-Sol assembly specifications require a 1-1/2 millimeter separation between the insulator and sleeve. The heater sub-assemblies prepared for the sample lot of 6080WB tubes had been made by an inexperienced operator, and the sleeves were pressed onto the heater leads abutting the ceramic insulator. In addition, the ceramic insulator was inserted into the cathode sleeve flush with the end of the sleeve rather than projecting 3/32-inch beyond the end of the sleeve. The result of these assembly errors was that the

edge of the ceramic insulator was chipped by the flattened heater sleeves during positioning of the leads for welding and the contact was made with the cathode. Neither the Tung-Sol operator nor Aeroprojects' representative was cognizant of these factors at the time of assembly.

As a result of these observations and evaluations, suitable modifications were made in handling, assembly, and sub-assembly inspection procedures, and a complete parts list for additional assemblies was prepared. This materials list included the special treatments, particularly annealing procedures, which were to be adopted for future tube assembly to insure consistent material properties. This list is presented in Table I.

Sufficient materials to initiate assembly of 300 tubes were requested of Tung-Sol (Table I). It was anticipated that the materials would be available and tube fabrication re-initiated early in October.

II. COMPONENTS WELDING

A. Tungsten-Rhenium Wire Welding

Preliminary ultrasonic welding of 0.003-inch-diameter tungsten-rhenium (W-3Re) wire to flat sheets of molybdenum, tungsten, and nickel was previously reported (Ninth Quarterly Progress Report, p. 4). Bonding achieved with a 100-watt welder was unsatisfactory because of insufficient power and clamping force capability. Investigations using a 600-watt welder indicated that bonding of the wire to each material could be achieved; however, the wire tended to split longitudinally during welding to the harder material (tungsten). The use of a grooved welding tip to nest the wire during welding (Tenth Quarterly Progress Report, p. 7) did not prevent the cracking, and the tip required constant redressing because wire fragments and debris became embedded in the groove.

In order to make a comprehensive survey of this problem, a 300-watt welder was used for final studies during this quarter. The clamping force range of the 300-watt welder allowed the use of forces intermediate to those available with the 100-watt and 600-watt welders. A comparison of the data obtained with the 300-watt and 600-watt units is presented in Table II.

These data indicate that satisfactory bond strength can be obtained using the magnetostrictive-transducer 600-watt welder to join tungsten-rhenium wire to nickel and molybdenum sheets. Joint strength obtainable with the tungsten sheet is limited because of splitting and fragmentation of the wire. The appearance of the welded joints is shown in the samples of Figures 1-3. Photomicrographs of the joints between the wire and the nickel sheet and between the wire and the molybdenum sheet are shown in Figures 4 and 5.

Table I

PARTS LIST FOR SAMPLE LOT 6080WB ELECTRON TUBES

Item	Tung-Sol Drawing No.	Special Requirements
Stems	81784B	Crimped, trimmed(1) and formed to Spec. Cleaned with isopropyl alcohol after forming.
Anode Support	43128	Cut to 41 mm length
Anode	28014A	Pinned with anode support. Assembly fired at 850°C for 30 min.
Top Spacer	16144B (AlSiMg)	
Top Spacer	16133B (Fotoceram)	
Lava Spacer	16116C	
Grid Eyelet	17727A	Fired at 850°C for 15 min.
Anode Eyelet	17758A	Fired at 850°C for 15 min.
Grid Assembly	68289	
Cathode Sleeve	25177	(Fired and coated.) Fired at 600°C for 15 min.
Cathode Tab	43143	Fired at 850°C for 20 min.
Anode Connector	17877(2)	Fired at 850°C for 20 min.
Heater Connector R.H.	17874	
Heater Connector L. H.	17875	
Heater, Heater Insulator Sub Assembly(3)	64543	
Snubber Support	43129	
Snubber	17861	
Top Cathode Connector	17879(4)	Pre-shaped according to Tung-Sol instruction
Cathode Connector	40038	
Grid Connector (Outside)	40039	
Grid Connector (Inside)	40041	
Getter	14069	

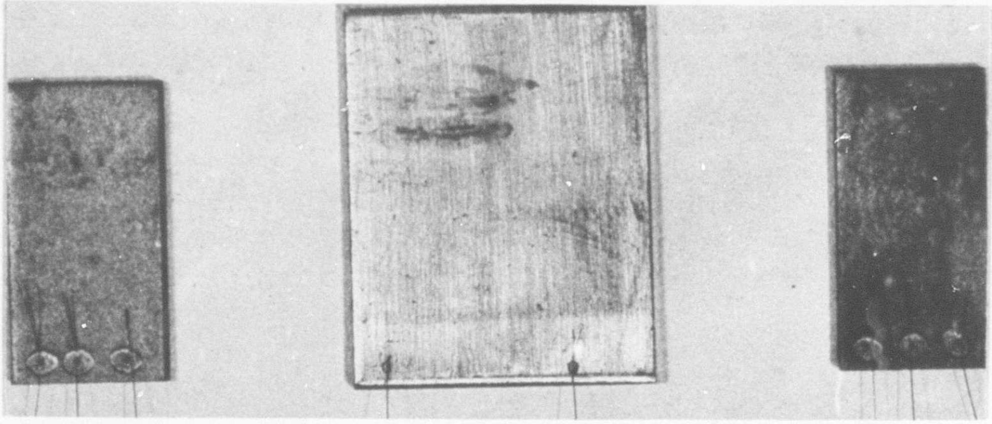
(1) Cut stem leads to gage block supplied by Tung-Sol.
(2) Only 17877 acceptable.
(3) Maintain proper spacing (1-1/2 mm) between insulator and flattened sleeve.
(4) Both ears to be 0.080 ± .005.

Table II

RESULTS OF WELDING TUNGSTEN-RHENIUM WIRE

Material Combination	Tensile-Shear Strengths (average pounds)		Joint Efficiency (percent*)	
	300-w Welder	600-w Welder	300-w Welder	600-w Welder
W-3Re to Ni	0.723	3.03**	22.5	95
W-3Re to Mo	0.327	2.78**	10.2	87
W-3Re to W	0.840	--	26.3	--

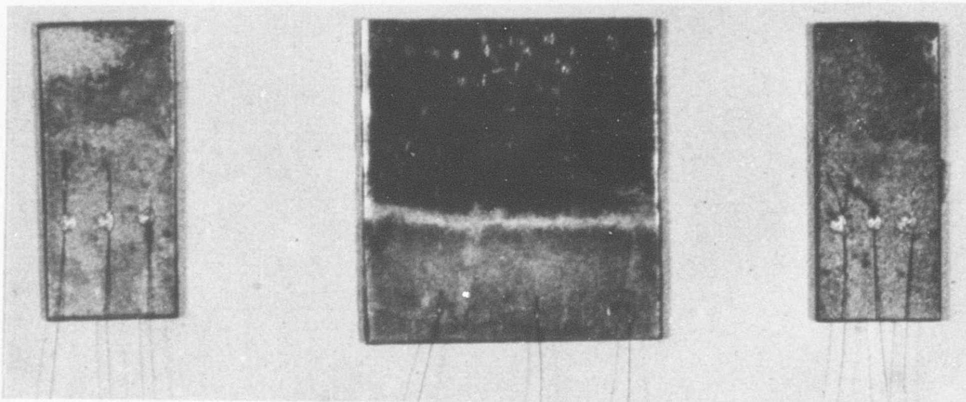
* Based on wire strength of 3.20 pounds.
** Wire broke off at edge of weld.



600 watt 300 watt 600 watt

Figure 1

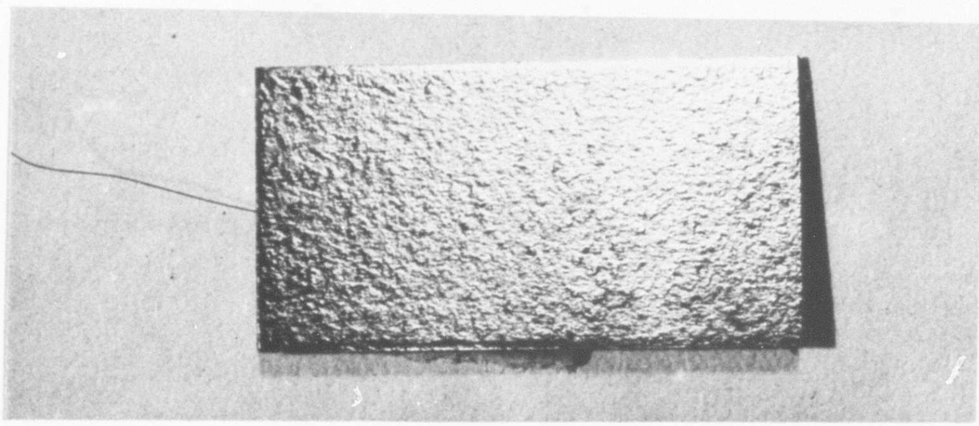
TUNGSTEN-RHENIUM WIRE WELDED TO NICKEL SHEET



600 watt 300 watt 600 watt

Figure 2

TUNGSTEN-RHENIUM WIRE WELDED TO MOLYBDENUM SHEET



300 watt

Figure 3

TUNGSTEN-RHENIUM WIRE WELDED TO TUNGSTEN SHEET

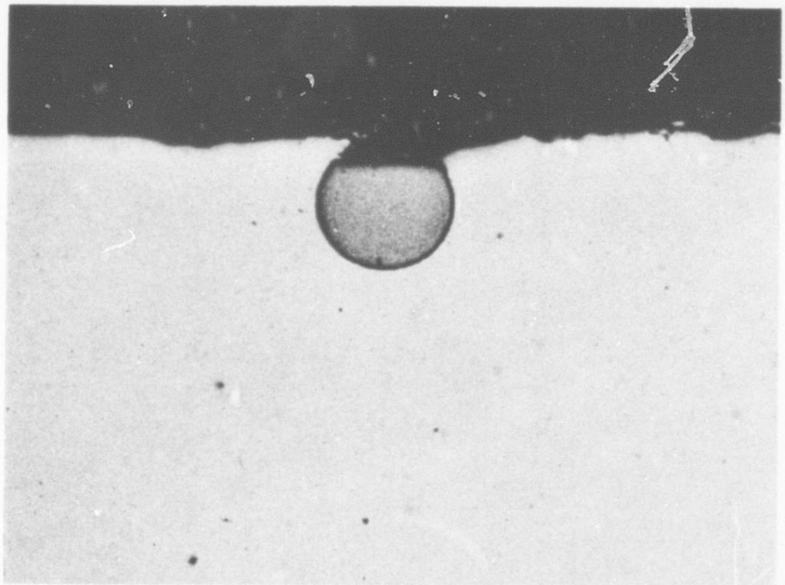


Figure 4

PHOTOMICROGRAPH OF 0.003-INCH DIAMETER W-3Re WIRE ULTRASONICALLY WELDED TO 0.060-INCH NICKEL PLATE

Transverse Section
Magnification: 200X
Etch: $KOH + K_3 Fe (CN)_6 + H_2O$

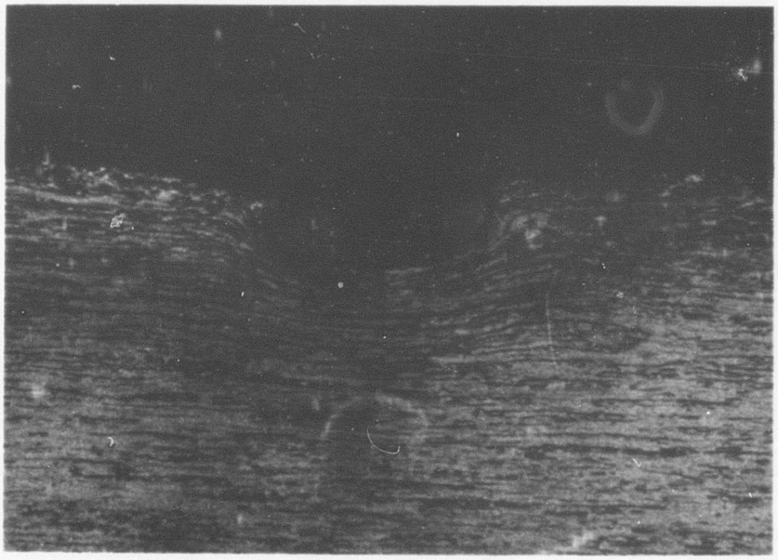


Figure 5

PHOTOMICROGRAPH OF 0.003-INCH DIAMETER W-3Re WIRE ULTRASONICALLY WELDED TO 0.060-INCH MOLYBDENUM PLATE

Transverse Section
Magnification: 200X
Etch: $KOH + K_3 Fe (CN)_6 + H_2O$

B. Frame-Grid Welding

Initial efforts to weld 0.003-inch-diameter gold-plated molybdenum wire to 0.060-inch-diameter molybdenum rods were conducted with the 600-watt welder (Tenth Quarterly Progress Report, p. 7). The approach was to weld one or two wires simultaneously and thus bond the laterals to the grid frame by successive welds. A welding tip with a double groove was used to accomplish two welds at a time. The separation of the grooves was established by the pitch of the wound frame grid assemblies supplied by Tung-Sol.

Power levels between 300 and 600 watts produced bonding of the laterals to the grid frame; however, deformation of the fine-diameter wire was high and occasional cut-through occurred. Since reduction of clamping force to minimize the deformation could not be readily accomplished with the standard 600-watt welder, consideration was given to utilizing a 300-watt welder with a lower clamping force range. At the suggestion of cognizant technical personnel of USAECOM, this approach was abandoned in favor of an investigation of the feasibility of welding all wire-wound turns on a single leg of the grid frame simultaneously, since complete frame-grid fabrication by individual or multiple turn bonding was considered to require too much time.

The 4-kw welder, constructed during this program, was used in these studies. Fixturing was provided to align the grid on the anvil surface. The welding tip was designed to contact all the turns on one side of the frame (approximately 45 turns, a weld line 1-3/16 inches long). A 1/2-inch cylindrical radius was used on the contact surface of the welding tip.

The available machine settings of the 4-kw welder were surveyed to determine welding conditions, but satisfactory bonding of all turns was not achieved. Each frame could be used for only one test, because the end straps of the grid frame broke loose during ultrasonic exposure and the frame collapsed. The straps fractured through the resistance spot weld used to join the end support straps to the legs. The cause of the fracture was observed to be the presence of pre-existing cracks in the end support strap, apparently resulting from the resistance welding operation. The crack is visible in the grid assembly shown in Figure 6.

The results of this study indicated that satisfactory bonding between the gold-plated molybdenum laterals and the molybdenum side rods could not be obtained using either the 4-kw welder to bond all turns simultaneously or the 600-watt welder to bond two turns at a time. No further work will be attempted on welding frame grids.

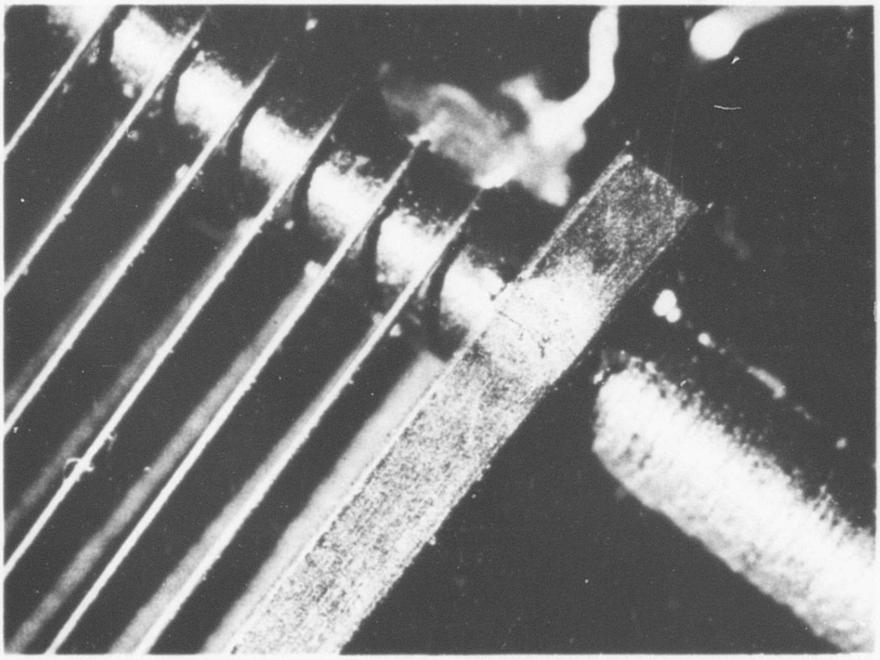


Figure 6

PHOTOGRAPH OF FRAME-GRID MAGNIFIED TO SHOW CRACK IN END SUPPORT STRAP THROUGH RESISTANCE SPOT WELD

III. CONCLUSIONS

All the welded joints in the sample lot of 100 type 6080WB electron tubes have been made by ultrasonic welding, except for the last step in the assembly sequence. Snubbers were satisfactorily joined to snubber support rods; however, fracture was induced in the brittle ceramic spacer, precluding the use of ultrasonic welding for this step in the assembly. The effect of ultrasonic welding cannot be evaluated with this lot, because the tubes are electrically defective on account of assembly errors not related to ultrasonic welding.

Tungsten-rhenium (W-3Re) wire 0.003 inch in diameter can be welded to flat sheets of nickel, molybdenum, and tungsten. Tensile-shear strengths of bonds between the wire and the nickel and molybdenum sheets obtained with a 600-watt welder are satisfactory; satisfactory welds were also obtained with a 300-watt welder, although joint strengths are lower. Attempts to weld the wire to the hard tungsten sheet with a 600-watt welder resulted in splintering of the wire, and bonding could not be achieved. However, satisfactory bonding was obtained for this combination with a 300-watt welder.

Ultrasonic welding of frame grids cannot be achieved by the several approaches examined within the limitations of the materials utilized in this study.

PROGRAM FOR NEXT INTERVAL

Attempts to solve the problem of spacer breakage due to part change in the last step of the assembly sequence will be continued.

It is anticipated that fabrication of a second sample lot of 100 type 6080WB electron tubes for life tests will be completed. Care will be taken with inspection during assembly.

TRIPS

The following trips were made in connection with this project:

Mr. T. A. Walraven visited Tung-Sol Electric, Inc., Bloomfield, New Jersey, for the purpose of assisting in the fabrication of the sample lot of 6080WB electron tubes on August 2, 9-12, 16-19, and 23-25.

Mr. H. L. McKaig, Jr., conferred with Messrs. Rodney Bell, M. Yarmovsky, and N. Helmstetter of Tung-Sol at the Tung-Sol plant on August 30 concerning steps to be taken to insure successful fabrication of a second sample lot.

TECHNICAL MAN-HOURS

EXPENDED DURING THIS REPORT PERIOD

Aeroprojects	Project	Hours Expended During This Report Period
J. G. Thomas	Project Engineer	45-1/2
T. A. Walraven	Senior Welding Technician	129
H. L. McKaig	Vice President	9
A. L. Fuchs	Chief Design Engineer	2
N. Maropis	Physicist	1
Engineering		88-1/2
Shop		20
	Sub Total	295

Tung-Sol Electric Incorporated		
Engineering		193
	TOTAL	488

Technical surveillance of this contract is under the control of the Industrial Engineering Division, USAECOM, Philadelphia, Pennsylvania 19103. For further technical information contact Mr. Harry Shienbloom, Project Engineer (telephone number: area code 215, KI6-3200, extension 2137).

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LEGEND

PROJECT SCHEI

PHASE I	Year	1962						1963										
	Quarter	1			2			3			4			5			6	
	Month	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
BASIC WELD STUDY								COMPLETED										
TUBE STUDY							COMPLETED											
WELDING EQUIPMENT (Construction)	- 100 w												COMPLETED					
	600 w												COMPLETED					
	4-kw												COMPLETED					
EQUIPMENT AND TOOLING CHECKOUT																		CC
W-Re WIRE WELDING STUDY																		
FRAME GRID WELDING STUDY																		
6080WB REDESIGN																		
PHASE II																		
WELDING EQUIPMENT (Delivery)	- 10C w																	
	600 w																	
	4-kw																	
INSTRUCTION MANUALS																		
REPRODUCIBLE DRAWINGS																		
SPECIAL SPARE PARTS																		
PHASE III																		
TUNG-SOL ACTIVITY																		
Training																		
Tube Assembly																		
Age and Test																		
Life Test																		
Data Compilation																		
METALLURGICAL EXAMINATION REPORT																		
QUARTERLY PROGRESS REPORTS				●			●			●			●			●		
FINAL SUMMARY REPORT																		

ND: ■ Proposed Work Schedule

▭ Work in Progress

○ Contractual Delivery Date

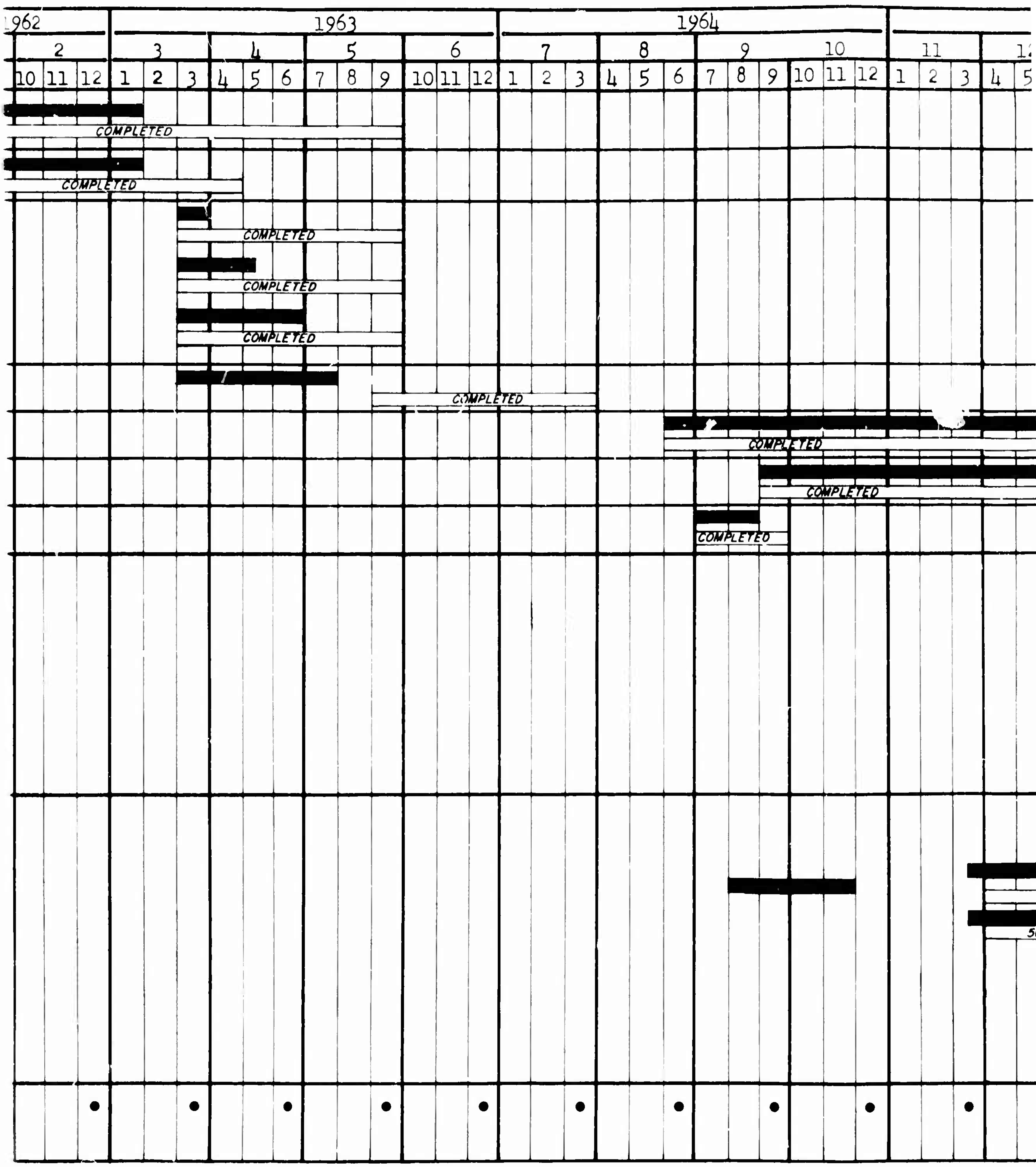
● Contractual Item Delivered

⊙ Amended Delivery Date

▨ Present Report Period

A

PROJECT SCHEDULE



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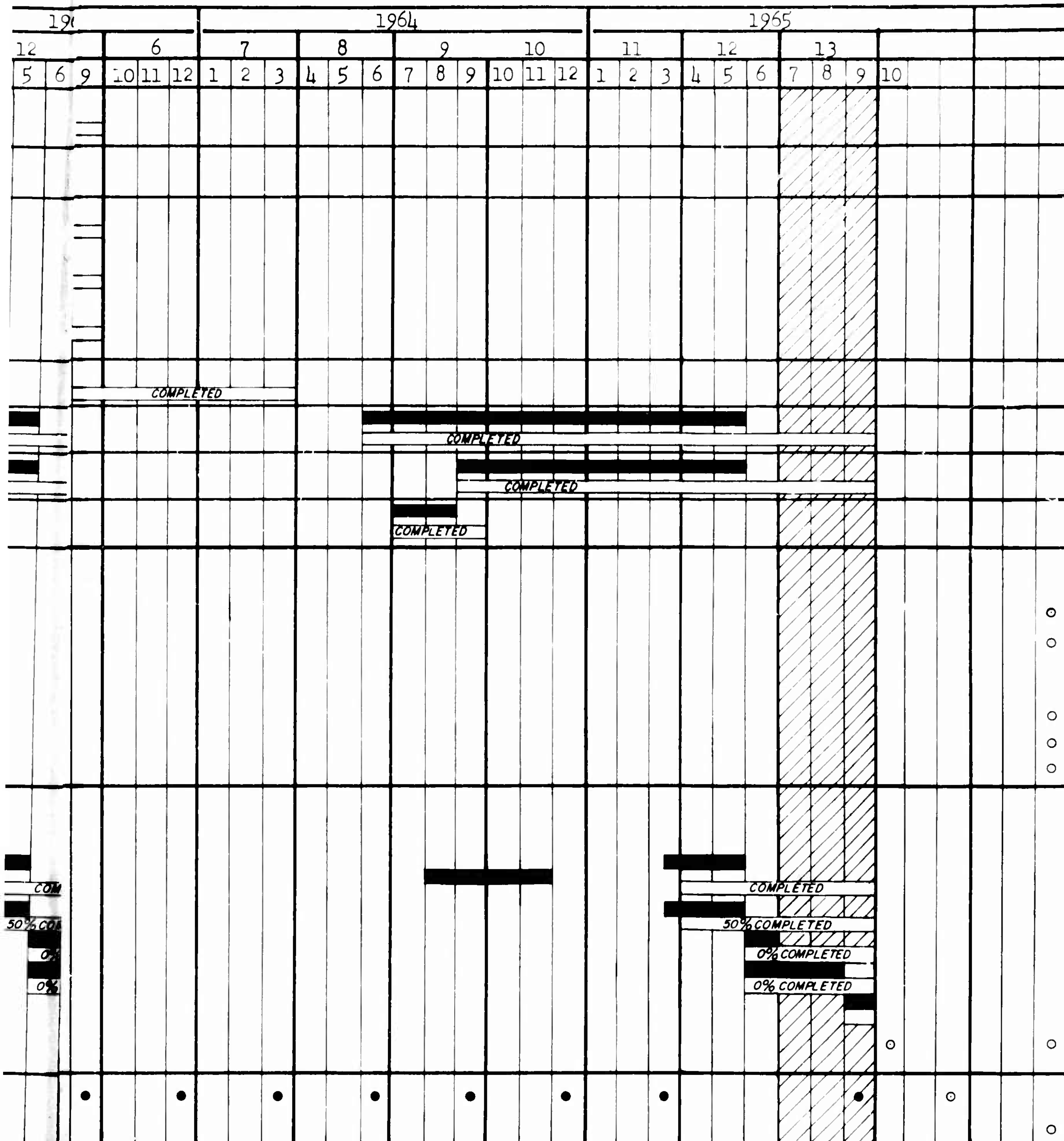
B

CT SCHEDULE



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